3.1. RATION FORMULATION

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INTRODUCTION

Formulating animal rations involves selecting and combining a number of feedstuffs to meet the animal requirements at the lowest possible cost, for the most economical level of production. In its most basic form, it has developed along with the domestication and keeping of livestock, and ration formulation as a daily farm practice requires knowledge on availability, price and composition of feeds. It also requires insight into the nutrient requirements of the animals. Ration formulation or a given level of production may not always result in an economically optimum level of production, as will be explained in this chapter. Different approaches are often used by extensionists and farmers to formulate rations, though their conclusions may be similar.

The following is a description of the historic development, background, principles of ration formulation, and of its relevance in different farming systems. A number of approaches to ration formulation are discussed, and illustrated with examples.

Handbook for Straw Feeding Systems
Kiran Singh and J.B. Schiere (eds.), 1995
ICAR, New Delhi, India

HISTORIC DEVELOPMENTS AND BACKGROUND

Livestock husbandry in early civilization involved feeding strategies based on whatever was provided by the natural environment. Animals were left to graze on vegetation abundantly available in those days, while they were hardly fed anything at home. Milk was produced without purchased inputs, and milk production levels per cow were generally low as compared to present levels. However, they were sufficient to meet the demand of small local populations, and low individual milk yields could be compensated by having a large herd.

Today, this ecological balance between supply and demand of animal products is gradually disappearing. Global expansion of population and consumption levels has resulted in an increased demand for milk and in a drastic reduction of the natural rangelands vegetation available for ruminants. Two necessities have evolved in livestock production from these processes of change:

- the need for increased milk production per animal to meet the present high demand for milk or cash needs, and
- the need to utilize more feeds from sources other than natural rangelands.

A man-made environment has evolved, using new methods replacing the old natural management techniques. The genetic ability for higher milk production levels has gradually increased, and animals are kept more and more in confinement and under controlled conditions with access to veterinary services. As far as the feed inputs in most farm systems today are concerned, insufficient feeds are produced on many farms to obtain the minimal income level required. This has prompted some farmers to purchase feeds from outside, creating a high market demand for feed and resulting in an overall price rise of feed ingredients as compared to the milk price. Other farmers face this problem and they are also forced to improve the utilization of crop residues that are available on-farm.

In such a situation, a farm/family, depending on its enterprise and production objectives, feels the need to control and regulate the supply of feeds to animals in order to sustain farm output and maintain the economic viability of the farm. Thus, a rational allocation of feeds is needed at low- and high-input farms, in such a way as to maintain the economic viability of the farm without affecting the desired production level of the farm. This is also known as ration formulation, and is being applied to an increasing extent in livestock farming systems today.

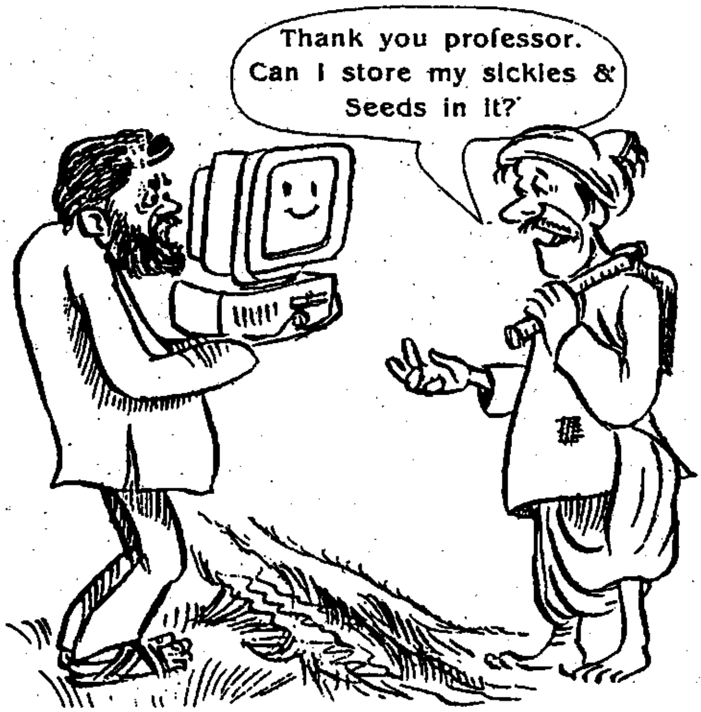
PRINCIPLES OF RATION FORMULATION

Ration formulation involves the selection and allocation of feed ingredients in such a way that the cost of the ration is kept low while sufficient nutrients are supplied to the animal for its maintenance and for its desired production level. Traditionally, farmers have used some sort of least cost ration formulation (LCRF) method to achieve this, which was based on farmers' experiences. Income maximisation is not always attained by LCRF, since the cheapest ration for an individual animal may lead to a suboptimal allocation of all available feeds to the herd as a whole. The optimal ration may be found through 'trial and error', but a farmer or extensionist may want to calculate it. One graph, or a few equations solved for a number of combinations, may get them close to the optimum, but if a computer is available, a simple linear program is most appropriate to find the answer. When the number of possible ingredients is large, linear programming (LP) on a computer can be useful to perform the required calculations. There is, however, quite some work to be done before computer information can be matched with farmers' expectations (Fig. 1). Ration formulation then becomes a purely mathematical process of minimizing the feed cost of a ration without affecting its feed value. Increasing feed prices and commercialization of dairy farms prompts farmers or feed companies to use LCRF in that way. The required information to apply LCRF consists of:

- the type and quantity of feed resources available in an area: agricultural and industrial (by)products;
- the concentration of energy (TDN), protein (CP) and other nutrients in each feed resource;
- the price of each feed resource;
- the nutrient requirements for maintenance, production, reproduction and growth functions of the animal;
- the maximum intake level of the animal;
- the desirable production level.

The usefulness and desired accuracy of feeding standards depend on the context and purpose of their application. Farmers develop standards by their experience of feed allocation as related to factors such as palatability, dry matter intake, fat content, production of milk and animal health, while scientists conduct experimental trials under controlled conditions. It is desirable that the use of standards developed by farmers and scientists are complimentary rather than mutually exclusive. Scientists often fail to understand farmers' values and priorities in low input farming systems.

Figure 1. Quite some work needs still to be done to match results from computer calculations with expectations and reality (Source: Honey Bee, Vol 4 (2&3), 1993)



RELEVANCE OF LCRF IN DIFFERENT FARMING SYSTEMS

A large variety of farming systems exists in India, due to differences in climate, geography and soil, as well as in family size, off-farm income and market prices. One of the important factors known to determine the relevance of LCRF in a particular system is the degree of external input use.

Low external input farming systems

The base of most Indian farming activity is a smallholder enterprise with one or a few animals, which are raised on roadside or bush grazing, or on feeding of crop residues and crop byproducts, done by family labour, often women. Although financial returns from the animals are low, they are still cost-effective (#2.2.). Over 60% of the milk output in the Operation Flood areas comes from these households.

Feed is a large constraint in this farming system. The feed availability is low and the situation further becomes critical due to regional and seasonal imbalances. Thus, in a low external input farming system, production is achieved mainly through grazing and grass cutting, straw feeding, and supplying an almost insignificant quantity of concentrate feed. For example:

> *A focused Rapid Rural Appraisal revealed that most poor farmers allocate concentrate only for two to four months, and only to lactating cows during the first phase of lactation. As soon as the supply of home-grown concentrate feed is exhausted, concentrate feeding is stopped.*

In a low-input farming system, periodic feed scarcities are coped with by allowing the animals to reduce their daily gain or even to loose body weight. Purchased feeds in such systems is not financially attractive, and LCRF needs to be applied in a different way, i.e. for medium of low, rather than necessarily high production levels.

High external input farming systems

Farmers in high external input farming systems purchase relatively large quantities of feed from the markets. Mostly, feed inputs are adjusted to the desired production level. In a high input farming system, sufficient feeds are purchased to increase the production level of high yielding crossbred animals. These farming systems have a good access to the market and remun erative produce prices.

A class of farmers, traditionally known as "GOWALAS", have been established for ages as specialised dairy farming communities in India. They follow a high input system, and in these production systems, farmers purchase various feeds at different prices. For them, LCRF is useful to maximise profit while minimising feed cost. Another class of farmers, i.e. those of the urban dairies are specialised in dairy production near large towns or cities, with excellent market facilities. Milk production on these farms is based entirely on purchased feed inputs, but many do not apply LCRF as a tool to economise on concentrate use for their targeted high level of production. Given the high milk price, the cost of concentrate is not so relevant for those systems.

AVAILABLE RATION FORMULATION METHODS

A few methods to obtain relevant information on optimal rations are now described. Each of them can be adapted for use under local conditions, such as the available resources, weather conditions, individual farming practices, cropping patterns, feeding practices and personal preferences.

Farmers' perceptions about feed value and ration formulation

Farmers have their own perceptions of the nutritive value of feeds, and they allot feeds to the animals strictly according to that (#2.2.). In that way, they can be said to use their own way of LCRF. Their practices are often based on traditional experiences and they may be quite appropriate (#2.3.). Some farmers believe that mustard oil cake (MO cake) is a "hot feed" and must not be fed to lactating cows. Others think that it can be fed during winter months only, and still others think that it can be fed in all seasons. A Bengali farmer even mentioned once on different grounds:

> *"Why should I waste MO cake by feeding it to my animals when I can also use it to fertilize my horticultural crops?"*

Traditional farmers' notions vary from place to place (Box 1). In the Districts Purulia and Bankura in West-Bengal, most farmers feed mustard oil cake round the year if it is available. In many areas, oil cake is fed along with mustard cake to 'neutralize' the so-called "hot" effect of mustard cake. Oil cake as such is considered to be a "cold" feed. Some farmers in villages think that boiled rice-grid should not be fed to cows during the first week of lactation, in order not to disturb the initiation of lactation. Many farmers think that feeding of bamboo leaves may help in bringing anoestrus cows into heat. Many such concepts exist in villages and they are worth further study (#2.3.).

In general, the livestock enterprise in rural India is managed by women. They receive occasional help from the male counterparts who are mostly engaged in other agricultural activities and who dedicate less time to the livestock enterprise. It is mostly the women that feed the livestock and know in their own way what to feed, when to feed, how to feed and how much to feed. They try to get the best possible output within the framework of resource constraints at their farm (Box 2).

Box 1. Some traditional feeding practices and results claimed by dairy farmers from semi-arid and tribal areas in Gujarat and Rajasthan (source: Pradhan *et al.*, 1993)

Material used	Feeding method	Animal type	Farmers' claims regarding effect
Cotton seed and Cotton seed cake	Cooked/soaked and with other material	Cows Buffaloes	Improvement in milk yield and fat%
Pods and seeds of *Acacia* and *Prosopsis*	Soaked/cooked and with other material	Cows Buffaloes Goats	Improvement in milk yield, fat%, inducing heat
Bibba seed	As such or with concentrates	Cows Buffaloes	Induces heat and oestrus signs
Tinosperma Cordifolia (creeper)	Green-both leaves and stems	Cows	Increases milk production
Tree leaves of *Alanguim salvifolium*, *Bassia latifolia* and *Butea monosperma*	Green Buffaloes	Cows milk Goats	Increases production
Flowers of *Bassia latifolia*	Fresh or after drying	Cows Buffaloes Bullocks	Improves milk production, maintains body condition
Prosopsis cinereria leaves and pods	Fresh, also as leaf meal	Cows Buffaloes Goats	Helps to maintain production
Maize cobs and cotton bolls	Cooked with other material	Cows Buffaloes	Liked by animals, maintains production

Box 2. Perceptions of women regarding livestock keeping (adapted from Rangnekar *et al.*, 1993)

Women's perception regarding livestock keeping provides an interesting field of study. Women in rich families generally have servants to look after the animals, and they themselves do not have a lot of interesting information regarding perceptions, except some communities like Rajput or Darbar, who considered livestock a status symbol. In many other cases, women were not even aware that their work constituted an important economic activity. They consider the care of cows and buffaloes as part of the usual household chore which is traditionally their responsibility. Just like house cleaning and cooking, animal care is not even counted as work. However, in villages where marketing of milk is organised and where development programs were initiated, the women did feel that they can earn substantial amounts by selling milk. These women would like to keep 3 to 4 milch animals, a number which they can manage in terms of labour input. Even these women still do not perceive dairy as a commercial operation, but as a source of supplementary income and as asset which can be encashed in times of need. Cow dung is an important produce - as fuel and source of manure. For women from pastoralist communities, the male progeny from the cows is more important than milk because they can be sold as draught animals. Grazing of animals is considered essential to maintain the health of the animals. Milk rich in fat is considered to be a better quality product than milk with a low fat concentration. Tribal women found it difficult to imagine that milk production could be an important economic activity and that a cow is capable of giving large quantities of milk. After a few visits, most women showed keen desire to know about high producing cows, artificial insemination, quality fodder, etc. Particularly from traditional cattle breeder communities, many women strongly believe that animals should be washed and kept clean to keep them healthy.

Least cost ration formulation for livestock in Indian farming systems exists in its own way. Farmers have their own perceptions, partly inherited from local traditions, about the quality of feeds. They try to balance animal rations in such a way as to keep the total costs at minimum, or better, to achieve maximum income. With local cattle, farmers usually are able to approach the minimum cost with the available resources, since the animal requirements in terms of quantity and quality are relatively low. With crossbred cows, in most situations higher quality feeds have to be purchased.

Although in those cases the total costs of the ration will increase, most farmers are able to realize low costs, and they are likely to be interested in technical support regarding LCRF from external agencies such as State Departments, State Agricultural Universities, Non-Governmental Organisations or even feed manufacturers.

Use of locally available extension material

In many states, extension materials are available in the form of leaflets regarding feed values of local feeds, ration formulation methods, and quantities to be fed to different species and classes of animals. They are often written in regional languages and in an easily understandable form, and are supplied to farmers by the State Extension Departments, the Agricultural Universities or Non-Governmental Organisations. This extension method may not be very exact, but mostly distinguishes sufficiently, for example between growing, lactating and dry animals, in order to be satisfactorily used by the farmer. Even so, the recommended ration often needs to be modified according to personal insights and particular seasonal feed availability. The advantage of such extension material is that it is written in local language and understandable terminologies, avoiding complicated technical terms.

The recommendation in percentages or parts is a risky method. For example, if an animal consumes a high quality feed, and the required amount of calcium (or any nutrient) is expressed as a percentage, e.g. 0.5%, then this percentage is to be doubled if a low quality feed such as straw is consumed. This is due to the limited intake of the straw. For example, a farmer may be advised a concentrate mixture as part of a straw-based ration for his or her dairy animal(s). This type of recommendation will only be reliable if the available feeds are classified in terms of their composition and dry matter percentage, and if the advise is given for a complete feed rather than for individual ingredients. The farmer does not have to know technical terms, nor perform a number of calculations to define the ration. An example of such recommendation per leaflet is shown in Table 1.

Table 1. Recommended diets and daily amounts (kg) for two groups of dairy animals

Ingredient	Animal type	
	Zebu cows	**Purebred Indian cows** **Crossbred cows** **Buffaloes**
Straw	4 kg	4-6 kg
Concentrate mixture for maintenance	1-1.5 kg	2 kg
Concentrate mixture for milk production	1 kg/2 litres of milk	1 kg/ 2 litres of milk
Concentrate mixture for gestation	1.25-1.75 kg additional	1.25-1.75 kg additional

When green fodder is available, the amount of concentrate mixture may be reduced at the rate of 1 kg concentrate for every 8-10 kg fresh green fodder. This type of information extended through leaflets to farmers by State Animal Husbandry Extension Departments, NGO's or State Agricultural Universities may be useful for use under village conditions, but requires clear language, careful interpretation and frequent updates under changing feed resource conditions.

Experimental rations may be tried out on-farm before making recommendations. An example of the joint investigation by farmers and researchers of economically viable options for improved feeding practices is described in Box 3.

Box 3. Ration formulation with locally available feeds: a village experience in Nadia District of West-Bengal, India (source: Saha and Singh, unpublished 1994)

Thirteen early lactating cows at thirteen different farms in Charsarati (Nadia District, West-Bengal) were fed, in addition to a basal ration of straw and roadside grass, a feed mixture containing:

40% mustard oil cake
40% rice kura
18% crushed maize

One kg salt and one kg of lime were added to every 100 kg of the above feed mixture. The calculated CP% and TDN% of this mixture were 18% and 73%, respectively. During 4 months, farmers fed their own concentrate and the experimental feed mixture in alternative months, while daily milk yields were recorded for each cow. All daily concentrate doses were based on the following rule of thumb: 1 kg per cow for maintenance, plus 0.5 kg concentrate per litre of milk. Each of the thirteen farmers fed his/ her own home-made concentrate in the first and third month, and the experimental diet in the second and fourth month. On average, the farmers realised an increased milk production of 600-900 g/cow/day with the experimental diet, whereas the feed cost per kg of milk remained equal on the two diets.

Nutrient requirement tables

The aim of using feeding standards is to optimize nutrition, and generally it does not consider social and economic factors. Economic optimization will have to be executed by selecting cheaper feeds, and by their judicious incorporation in the ration, either calculating by hand, calculator or computer. Box 4 describes feeding standards for low-input animal production systems.

Box 4. Feeding standards and feed requirements

Feeding standards for low-input animal production systems in temperate systems have been developed by the Agricultural Research Council in the U.K. and by the National Research Council in the U.S.A. They have been discussed for survival feeding by Cronjé (1990). Various attempts have been made to develop feeding standards for India. Ray and Ranjhan (1978) based their recommendations on studies of basal metabolic rates, mostly conducted on IVRI, Izatnagar and feeding trials conducted at other research stations of the country. ICAR also published the nutrient requirements for cattle, buffaloes, sheep, goats, camels, poultry and swine, the most recent set of nutrient requirements is Ranjhan (1990). The publication by Kearl (1982) on nutrient requirements for the developing countries was partially based on such Indian work. The application of feeding standards developed for high input systems for use in low input systems is doubtful and needs to be done with care (Ketelaars and Tolkamp, 1991; Schiere and de Wit, 1993).

Linear programming

The use of computers for extension and/or personal use is facilitated in recent years by the increased availability of computer software and hardware in most parts of India. Linear programming (LP) can be used for development and/or evaluation of a ration under low input conditions. However, its application and use is in most cases restricted by the lack of information on the quality and quantity of locally available (affordable) feeds, as well as by the knowledge about optimum levels of production. However, the use of computers can be effective when such data are available and when there is a realistic expectation of cost reduction by applying LP. Box 5 describes the basic LCRF approach when it is to be tackled by linear programming.

Box 5. The basic linear programming problem for LCRF

The following example describes the formulation of a ration consisting of forage and concentrate. One kg of forage costs 4 Rs and contains 10 MJ, 8% CP. One kg of concentrate contains 20 MJ, 24% CP and costs 10 Rs. Thousand kg of ration is to contain a mixture of forage and concentrate, such that its cost is minimized while energy and protein concentrations exceed 12 MJ/kg and equal 16%, respectively.

Characteristic	Unit	Forage	Concentrate		Constraint
Cost	INR *)	$4 * X_A$	$10 * X_B$		Minimize
Weight	kg	$1 * X_A$	$1 * X_B$	=	1000 kg
Energy	kJ ME/kg	$10 * X_A$	$20 * X_B$	>=	12 * 1000 kg
Protein	% CP	$8 * X_A$	$24 * X_B$	=	16 * 1000 kg

The least expensive combination of green fodder and concentrate can be found by transforming the above information into a set of equations. The solution can be found either graphically, by hand, calculator or computer. When this is done, it will be found that the least expensive solution to this problem is to mix 750 kg forage with 250 kg concentrate. The mixture will contain 16% CP and 12.5 kJ ME per kg. Even though the outcome in the case of two feeds with only TDN and CP will be rather obvious, the problem becomes much more complicated when three or more feeds, and more constraints are included. One constraint should be the maximum dry matter intake by the animal, which is limited by the quality of the feed. The solution dictated by a linear model is sensitive to the input parameters and conditions assumed in the model. A sensitivity analysis may indicate the parameters that most influence the answer. These parameters can be refined to yield more accurate answers with the model.

*) INR = Indian Rupees
X_A = weight of feed A (kg)
X_B = weight of feed B (kg)

CONCLUSION

Ration formulation can be undertaken in several ways. For most farmers and at present, LCRF with linear programming is not recommended for defining local rations. For extension workers without access to, or sufficient acquaintance with the required hardware and software, it may be difficult to yield any fruitful message with this method. At this stage, suitable technical bulletins in an easily understandable language may be the most appropriate tool to help farming communities in formulating optimal rations for their animals. Nevertheless, LCRF with or without linear programming has a role to play in the future of Indian livestock development, provided that it takes into account the farmers objectives of keeping animals, not only high biological yields.

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